Discovery of a "Frozen-in" Anticyclone in the Spring and Summer Arctic Stratosphere in EOS MLS Data

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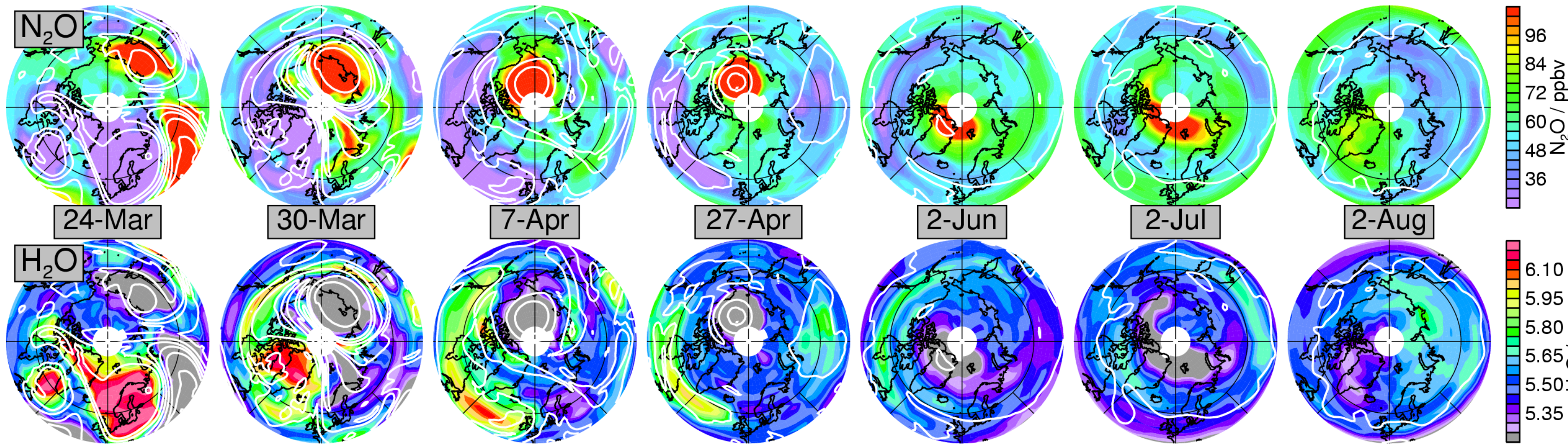
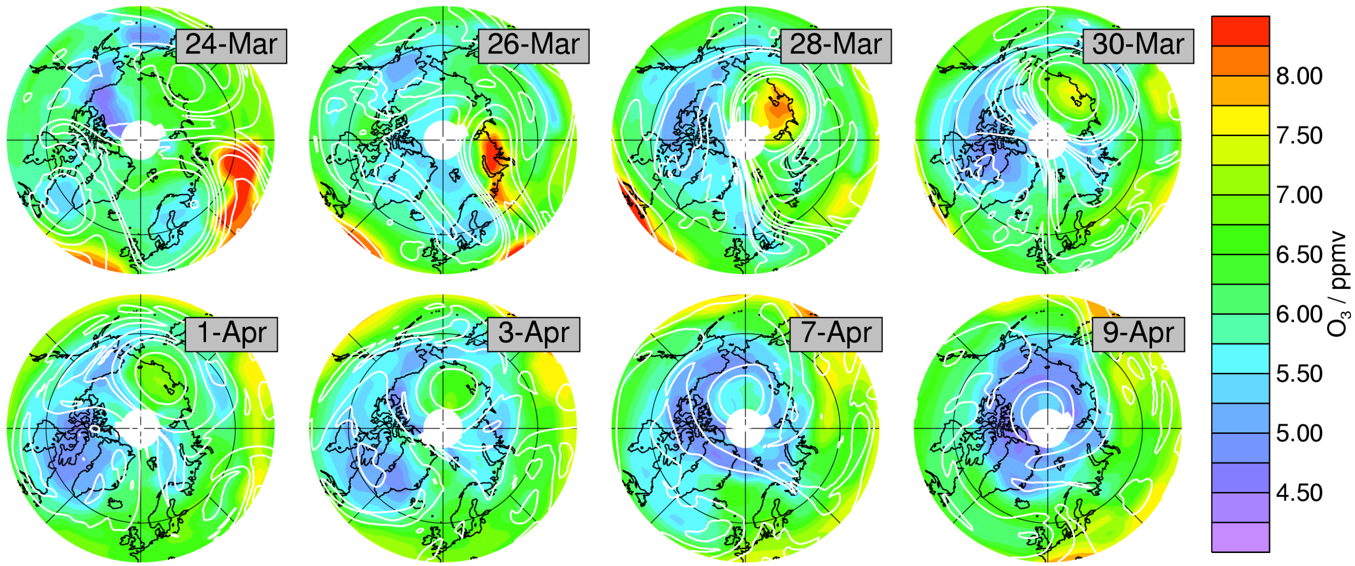
Aura Science Team, November 2005

Introduction — Maps



- ❑ 850 K (∼32 km, 10 hPa) maps of MLS N_2O (top row) and H_2O (bottom row) show a previously unreported phenomenon discovered during routine inspection of MLS data.
- ❑ The 2005 Arctic vortex broke up in a "major final warming".
  - ⇨ A warming leading directly to the final warming with no significant intervening recovery.
- ❑ Many tongues of low latitude air were drawn to high latitudes.
- ❑ Starting on the 24th March, one of these formed a tight, closed anticyclone which persisted through to mid-summer.
- ❑ This was advected westwards round the pole with little dissipation.
- ❑ This is analogous to "frozen-in" vortex remnants, such as reported by e.g., Orsolini [2001].
- ❑ Corresponding PV feature (overlaid white contours) disappears by early June.

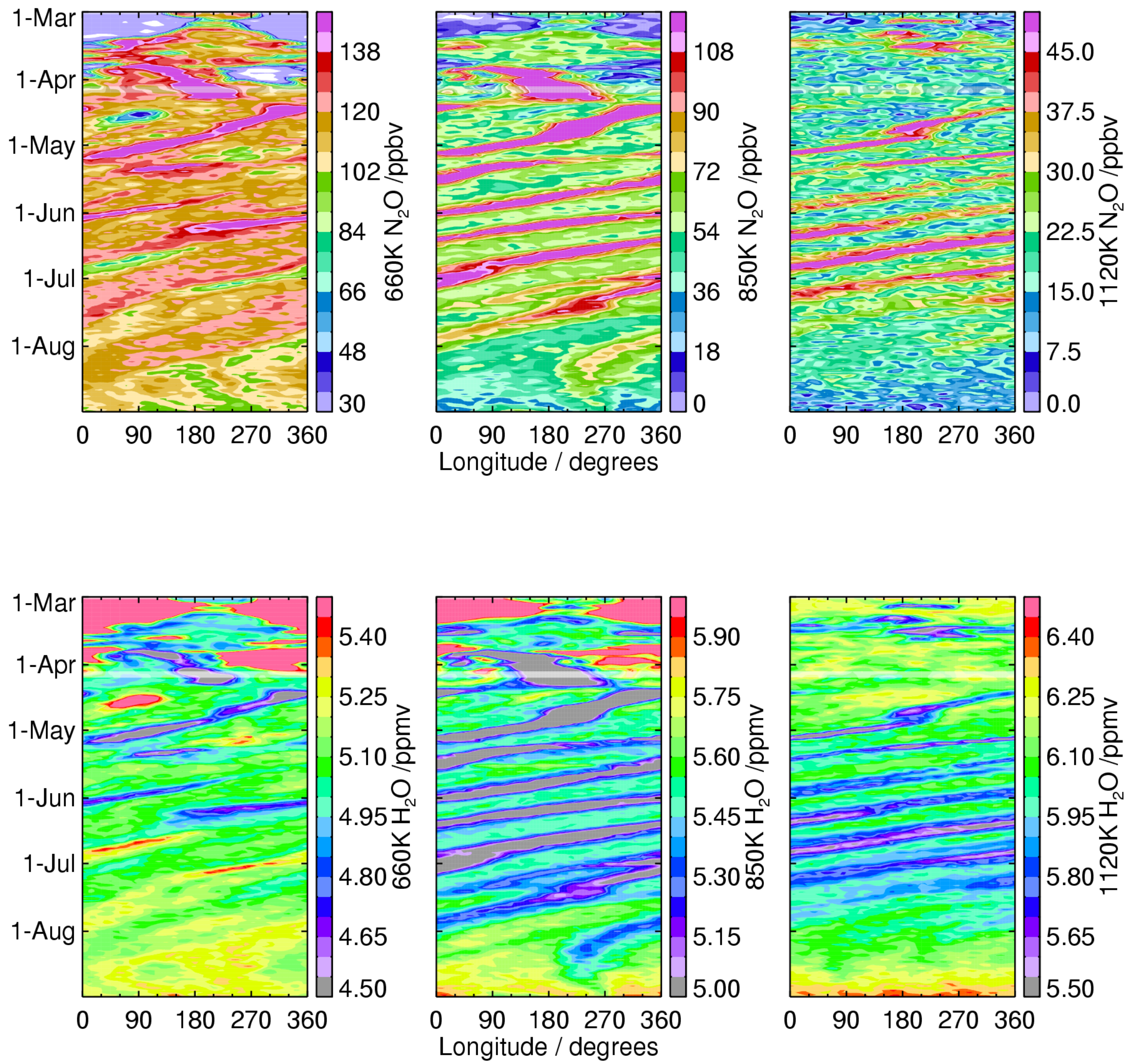
Signs of the FrIAC in 850 K Ozone data



- ❑ High ozone air drawn up from lower latitudes is confined in anticyclone.

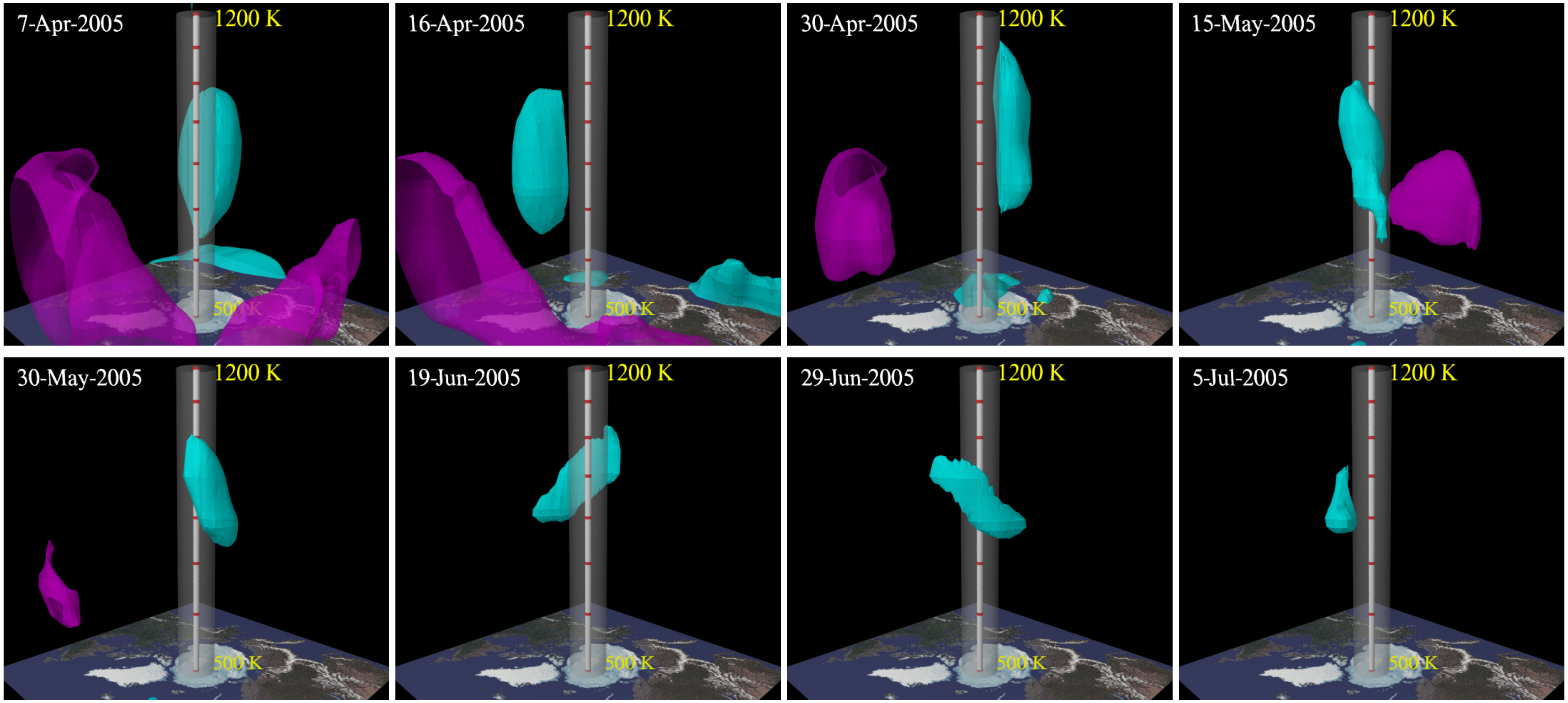
- ❑ Ozone quickly relaxes photochemically to values typical of high latitudes.
- ❑ Ozone is the only trace gas with many previous global profile measurements covering the spring/summer period.
- ❑ However, features of this sort would not be detected in ozone.
- ❑ Examination of 1992 and 1993 PV fields (when CLAES data were available during some parts of the relevant period) show no suggestion that there should have been a FrIAC in those years, and CLAES data show no signs of one.

The temporal evolution of the FrIAC (78°N)



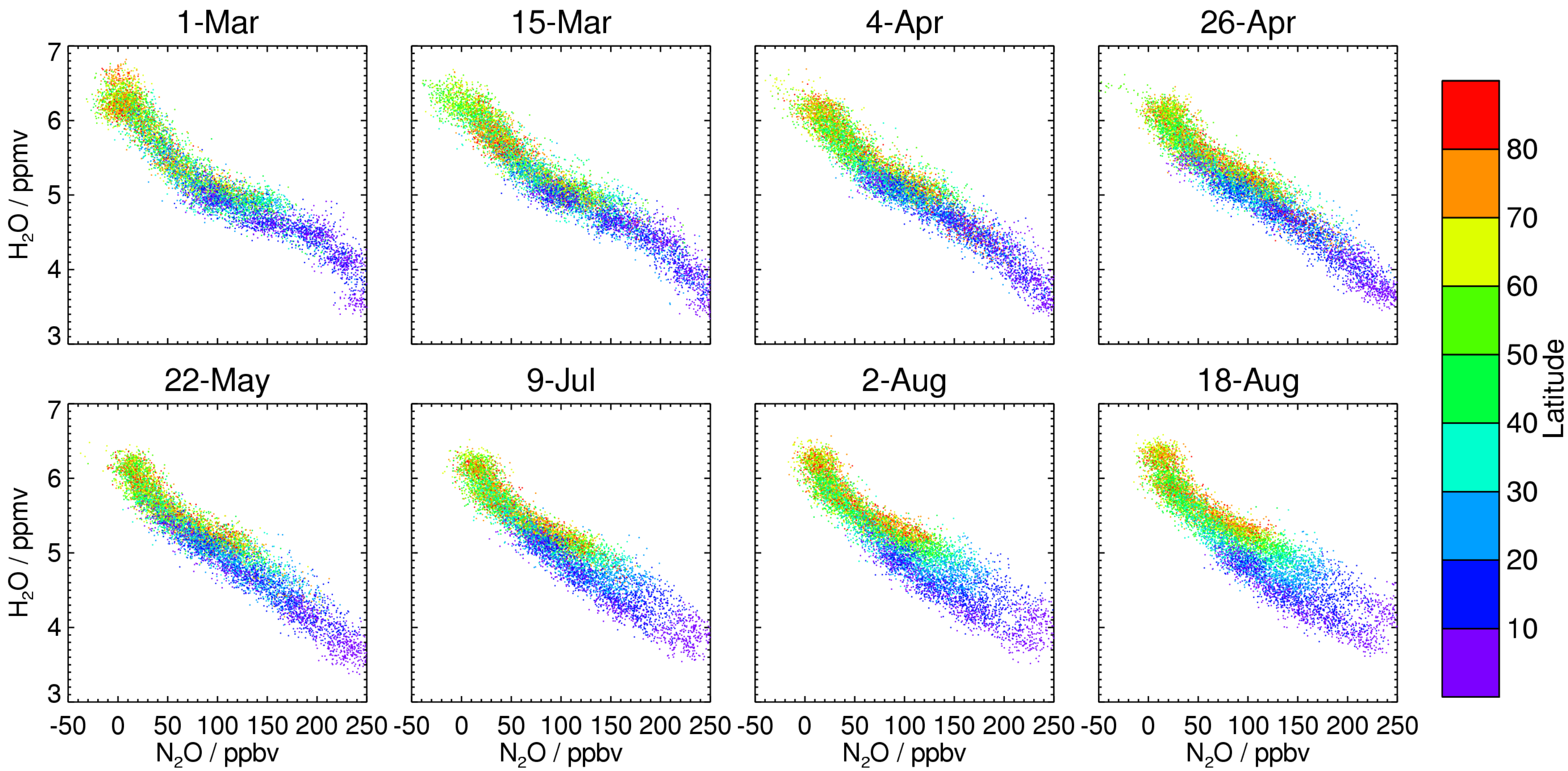
- Feature persists through July.
- Vertical extent 650 K – 1200 K.
- Advected by summer easterly winds.
- The weak shears contribute to its longevity.
- Anticyclone stalls & dissipates only when winds weaken in early August.

A 3D view of the FrIAC



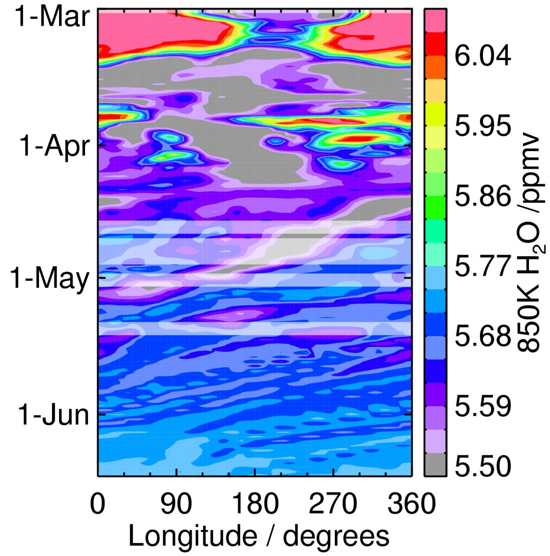
- Deviation of N_2O from NH mean profile (11 March to 18 July 2005).
  - ⇨ Cyan volume is anticyclone, N_2O anomaly >15 ppbv.
  - ⇨ Magenta volume is vortex remnant, N_2O anomaly < -90 ppbv.
- April/May shows FrIAC well established with vortex remnant evident.
- Later frames show the moderate shearing and dissipation of the FrIAC.

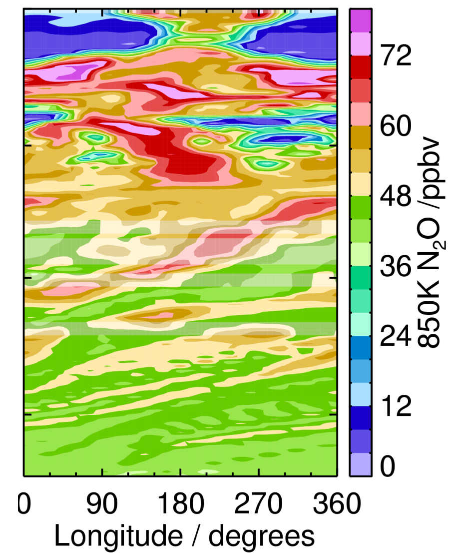
Tracer–tracer correlation studies



- The FrIAC appears clearly in the scatter plots as high latitude (red) air with higher N_2O, lower H_2O characteristic of lower latitudes.
- Increasing amount of this as FrIAC forms when low latitude air is drawn into polar regions.
- Early plots show changes in slope related to polar vortex transport barrier.
- As this is "mixed out" in summer, high-latitude air spreads more along correlation curve.

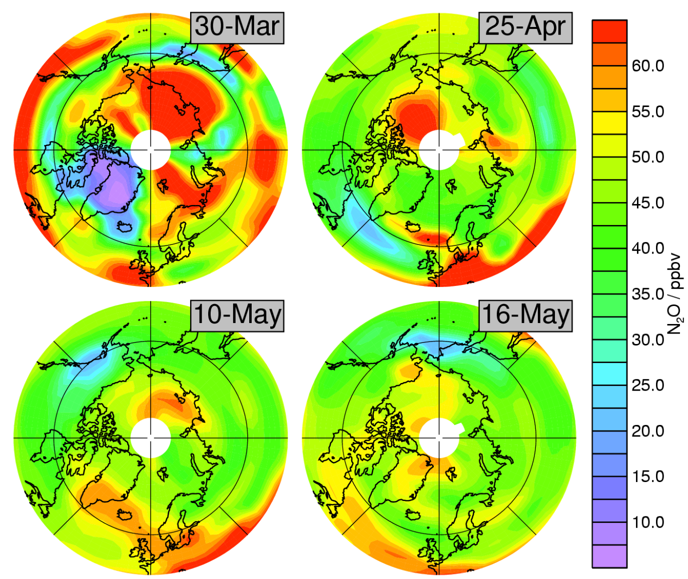
SLIMCAT model simulations



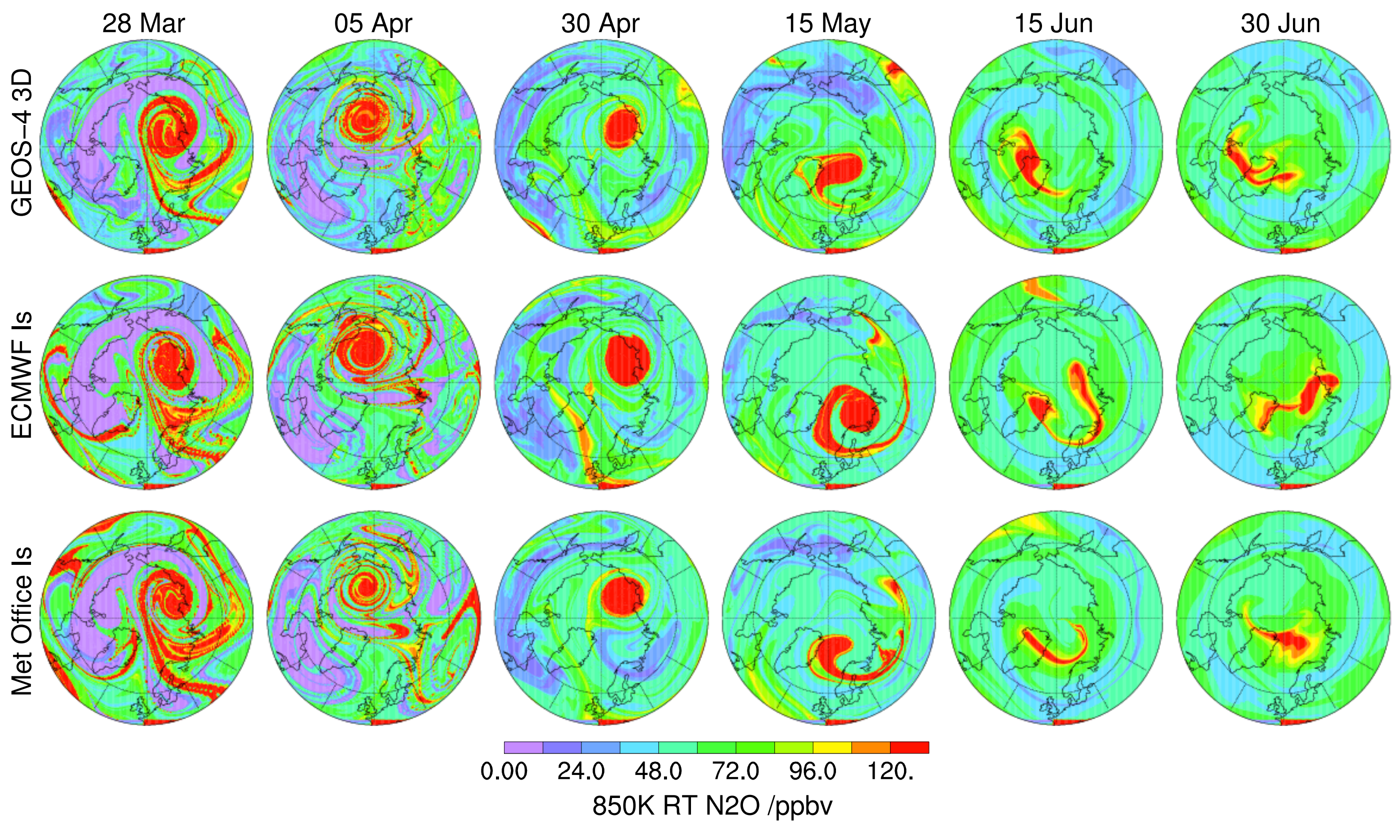


- ❑ 850 K H_2O (left) and N_2O (right, below) SLIMCAT fields.
- ❑ Model is run near-real time, driven with Met Office analyses and sampled at the MLS profile locations.

- ❑ The model captures the FrIAC formation in a realistic manner.
- ❑ However, the N_2O and H_2O dynamic range is smaller than seen by MLS.
- ❑ Also, model shows the feature disappearing by early June (MLS shows early August).
- ❑ Maps of SLIMCAT data show unrealistic ‘shredding’ of feature.

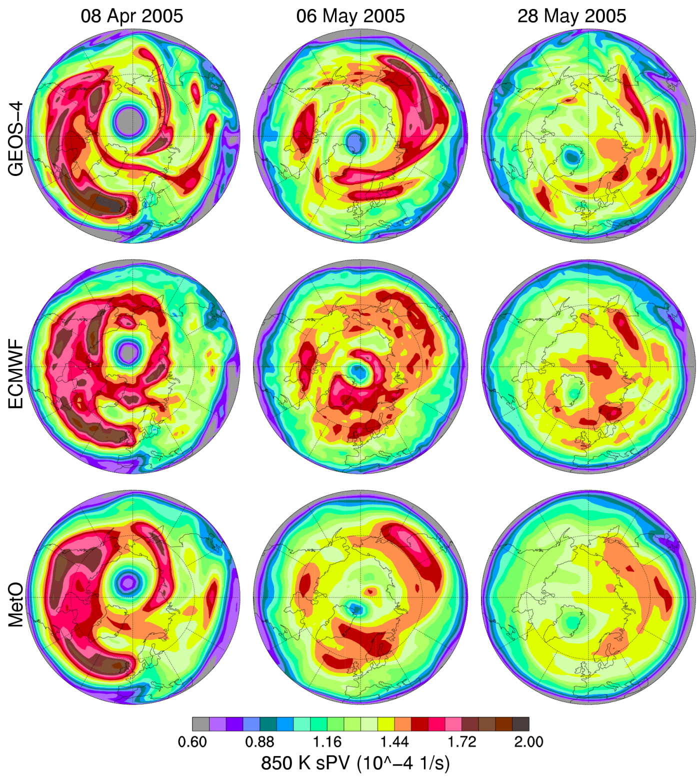


High resolution trajectory studies

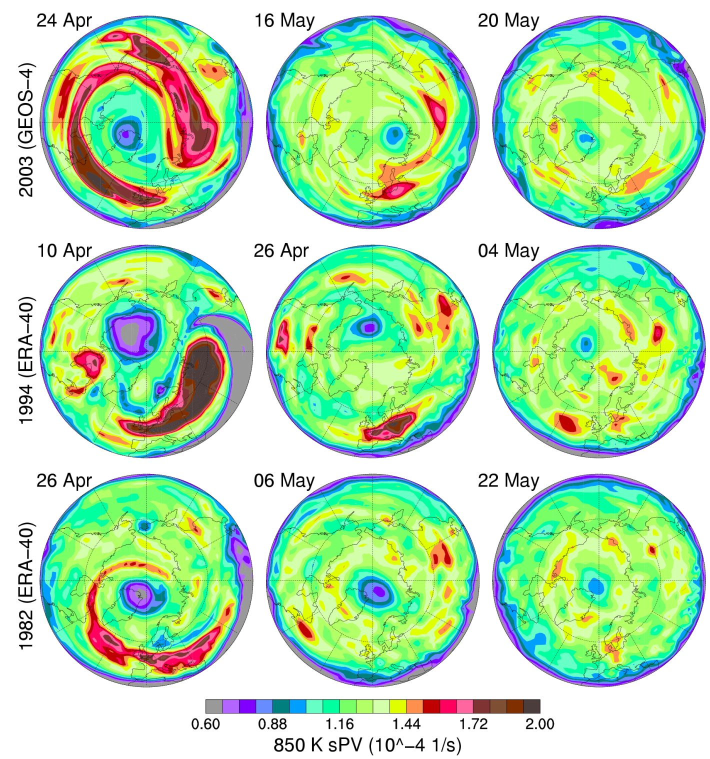


- 16-day reverse trajectory calculations initialized with MLS N_2O.
- The feature reproduced well in the early stages, but by end of May it shreds unrealistically.
- Similar behavior is seen in the SLIMCAT calculations shown earlier.
- Meteorological analyses differ in detail, but all fail to preserve the FrIAC.
- Suggests unrealistic dispersion from all analyzed winds in summer – provides a stringent test of high-latitude summertime winds.

The FrIAC in PV and historical perspective



- ❑ 850 K PV maps from different analyses (left) show substantial differences.
- ❑ Lower resolution Met Office fields suggest FrIAC dissipates sooner.
- ❑ PV fields only way to identify FrIAC in previous years, when we have no global daily long-lived trace gas data – difficult to assess quality of PV maps.



- ❑ Survey of GEOS-4, ERA-40 and MetO PV fields for previous years suggests FrIAC may have occurred several times.
- ❑ 1982, 1994, 2003 (right) are the strongest possibilities; 1997 and 2002 also suggest sustained anticyclone, as well as several years in earlier (pre-80s) ERA-40 data.

Summary and conclusions

- Aura MLS tracer observations have provided the first observations of a "frozen-in" region of low-latitude air in the northern polar regions following the Arctic vortex break up, extending from 650 K – 1200 K.
- It was advected in the easterly winds, staying 'upright', and persisted from 24th March to mid August 2005.
- Its signature in ozone has a far shorter lifetime due to chemical effects.
- PV fields, modeling studies and trajectory calculations capture the formation of the feature well, but fail to reproduce its stability and longevity.
- Good modeling of this feature could be a useful stringent test of summer stratospheric wind fields.
- We'll investigate whether previous FrIACs were sampled by other instruments.
- It is unlikely that a FrIAC could be reliably identified without global daily long-lived trace gas data such as that provided by EOS MLS.